Physics 9HB: Relativity and Thermal Physics

Jim Crutchfield
chaos@cse.ucdavis.edu; cse.ucdavis.edu/~chaos

Winter 2007
WWW: cse.ucdavis.edu/~chaos/courses/9hb/

Mid-Term Exam (13 February 2007)

YOUR NAME: _____

INSTRUCTIONS: This is a closed-book, closed-notes exam. You are allowed to use a calculator, a ruler, and an 8.5-inch x 11-inch sheet of paper (both sides, if you like) as "cheat sheet", but no other aids. Fill in your name on the line above on this sheet. Do your work on regular 8.5" x 11" paper and attach your answer pages to this one. (There'll be a stapler.)

NOTE: Please show your work: You should explain your physical reasoning and show your mathematical work in full. Getting the "right answer" in itself will only earn you a small fraction of the possible credit on a problem. Generous partial credit will be given for all aspects of your work on a problem, so do whatever you can for every problem on the test. Be sure to include correct units for all numerical quantities.

Total of 100 points:

1. 4 basic skill problems, each worth 10 points.
2. 3 synthetic problems, each worth 20 points.

PROBLEMS:

1. (10 points): Clock P is at rest alongside a racetrack. A jockey on horseback checks her watch against clock P as she passes it during the first lap (call this event A) and then checks her watch again as she passes clock P the second time (call this event B). (a) Which clock (clock P or the watch) measures the spacetime interval between events A and B? (b) Which measures proper time? (c) Do either of the clocks measure coordinate time between the events in the ground frame? Explain.
2. (10 points): An event occurs at $t = 6.0$ s and $x = 4.0$ s in the Home Frame. When and where does this event occur in an Other Frame moving with speed $\beta = 0.50$ in the $+x$-direction with respect to the Home Frame? Answer this question using a two-observer spacetime diagram; check your work using the appropriate Lorentz transformation.
3. (10 points): How fast does an object have to be moving in a given frame if its measured length in that frame is one-half its rest length?
4. (10 points): A particle of mass m at rest decays into two identical particles, each with mass $\frac{1}{3}m$. Conservation of spatial momentum means that the product particles have to move off in opposite directions with the same speed. What is the relativistic kinetic energy of each particle?

5. (20 points): A jogger runs exactly 22 times around an 0.5-km track in 48 min, as measured by a friend sitting at rest on the side. If the jogger and friend synchronize watches before the run, how much are they out of synchronization afterward? Is this the reason that many people expect joggers to live longer than people who don't jog? Explain.
6. (20 points): We have blithely spoken about trains traveling at significant fractions of the speed of light during the course. If electrical energy costs about \$0.04 per 10^6 J, what would it cost to accelerate an electric train with a mass of about $100,000$ kg to a speed of $\frac{3}{5}$?
7. (20 points): A Tirillian spaceship fleeing from battle passes space station DS7 at an essentially constant velocity of $\beta = \frac{3}{5}$ in the $+x$ direction as measured in DS7's frame. Let the event of the ship passing DS7 be the origin event A in both frames. The Tirillians have a cloaking device that they think makes them invisible to DS7's sensors. However, 40 s after passing DS7 (as measured by the Tirillian clocks) the spaceship passes through a dust cloud that emits a pulse of electromagnetic radiation when disturbed; let this be event B. The instant that this pulse (which travels at the speed of light) is received by DS7, the DS7 crew fires a photon torpedo (which also travels at the speed of light) toward the fleeing Tirillians; call this event C. The Tirillians decide 80 s after passing DS7 that they have likely been detected, so they put up their defensive shields (which involves turning off the cloaking device); call this event D.

   (a) Draw a complete and carefully constructed two-observer spacetime diagram of the situation, drawing the worldlines of DS7 and the Tirillian spaceship and locating and labeling events A, B, C, and D.

   (b) When and where did even B occur in the Home Frame? Use an appropriate Lorentz transformation equation to check what you read from your diagram.

   (c) When does event C occur in the Home Frame? Explain how you located this event on the diagram.

   (d) When does event C occur in the Tirillian frame? Explain how you can read t'_C from the diagram. Use an appropriate Lorentz transformation equation to verify your result.

   (e) Which event, C or D, occurs first in the DS7 frame? Which occurs first in the Tirillian frame? Explain your reasoning.

   (f) Is it possible that the Tirillians could have made their decision to raise the shields as a consequence of observing (somehow) that DS7 had fired a torpedo? Why or why not?